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(54) **STATIC FLUID FLOW MIXING APPARATUS**

STATISCHE VORRICHTUNG ZUR STRÖMUNGSDURCHMISCHUNG VON FLUIDEN

DISPOSITIF STATIQUE DE MELANGE D'ECOULEMENT DE FLUIDE

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Description

[0001] The invention relates to a static mixer comprising a longitudinally elongated conduit having tabs that are arranged with respective first edges adjacent the conduit wall, and respective opposed second edges that are spaced radially inwardly from the conduit wall, said mixer further comprising a central body extending generally coaxially along at least a portion of the longitudinal extent of said conduit and defining between said central bodies surface and said conduit wall, an annular space.

[0002] Furthermore, the invention also relates to the use of such static mixer.

[0003] More generally, the invention relates to static mixers, and especially to static mixers having both radial and longitudinal flow in an elongated fluid-mixing conduit.

[0004] As a generalization, typical static mixers include fluid redirecting tabs, vanes, baffles or the like, that are arranged in a fluid conduit, and which are typically operable to divide, subdivide, separate adjacent subdivided flows, and then recombine the subdivided flows into a "shuffled" whole, as the fluid passes through that conduit.

[0005] In a departure from that more typical approach, US-A-4 929 088 discloses a tab arrangement in a fluid conduit that has lower fluid back-pressures than are associated with the more typical approach to more typical static mixer designs. In particular, this known tab arrangement operates by creating radial vortex flow patterns that are generally transverse to the longitudinal flow through the fluid conduit in which these tabs are mounted. This results in a plurality of cross-stream mixing flows that are transverse to the longitudinal flow of the fluid along the length of the conduit. This approach is disclosed as an enhancement over the kind of mixing that would be expected to naturally occur in a conduit under turbulent fluid flow conditions.

[0006] Furthermore, a static mixer of the type mentioned in the beginning is disclosed in DE-A-539 423, in which however the fluid redirecting means do not have the form of pads and are thus not operable as fluid foils.

[0007] Finally, GB-A-1212633 discloses an irradiation apparatus comprising mixing means in the form of pads, which pads however, in contrast to the present invention, are arranged in the irradiation apparatus.

[0008] In accordance with the present invention there is provided an improved static mixer of the type mentioned in the beginning, which is characterized in that said tabs are operable as fluid foils which, with fluid flowing through said mixer conduit, have greater fluid pressures manifest against their upstream faces and reduced fluid pressures against their downstream faces, and wherein a resultant pressure difference in the fluid adjacent, respectively, the mutually opposed faces of each of the tabs causes a longitudinal flow of fluid through said conduit over and past each said tab, to be redirected, thereby resulting in the addition of a radial

cross-flow component to the longitudinal flow of fluid through the conduit.

[0009] Thus, a central elongated body is deployed within the static mixer conduit, in a central region of reduced mixing. Such a region, for example, tends to exist between diametrically-opposed, radially-convergent, cross-stream mixing flows within that conduit. In any case, this centrally-located body occupies a zone in which there would otherwise be a reduced cross-flow. The presence of this central body results in the fluid flowing past it tending to be more efficiently mixed - in that there is less of a tendency for an unmixed "channel" of longitudinal fluid flow to establish itself within the centre of the conduit.

[0010] Furthermore, tabs are each arranged with respective, (preferably leading, upstream) edges adjacent the conduit wall, and respective, (preferably trailing, downstream) opposed edges that are spaced radially inwardly from the conduit wall. These tabs are operable as fluid foils which, with fluid flowing through the mixer, have greater fluid pressures manifest against their upstream faces and reduced fluid pressures against their downstream faces. This pressure difference in the fluid adjacent, respectively, the mutually opposed faces of each of the tabs then causes the longitudinal flow over and past each tab to be redirected, thereby resulting in the addition of a radial cross-flow component to the longitudinal flow of fluid through the conduit.

[0011] The present invention further includes the use of the static mixer according to the present invention for mixing a fluid flowing through said conduit, wherein radial cross-stream mixing results from said flow redirecting tabs redirecting a longitudinal fluid flow from the conduit wall across an intervening space of annular cross-section towards the surface of the inner body. Thus, the static mixing is performed over a longitudinal extent of a mixing volume having an annular cross-section. More specifically, the use of the present invention relates to cross-stream mixing in a fluid flow, in which tabs mentioned herein redirect a longitudinal fluid flow from an outer, fluid containment boundary surface, across an intervening space having an annular cross-section towards an inner boundary surface. Preferably, the tabs are ramped and arranged in the fluid flow between the respective boundary surfaces, to cause the fluid to flow over the edges of each such tab to deflect the generally longitudinal fluid flow inwardly from the fluid containment boundary surface, across the intervening space (having the aforesaid annular cross-section), towards an inner boundary surface. The inner boundary surface defines a volume which but for the presence of that surface, would permit passage of a central longitudinal flow of non-uniform fluid mixing.

[0012] In a particularly preferred form the fluid flow over the edges of each tab results in the flow being deflected inward and up the inclined surface of the tab to generate a pair of tip vortices in the fluid flow past each tab. The vortices of each such pair have mutually op-

posed rotations, about an axis of rotation oriented generally along the longitudinal "stream-wise" fluid flow direction, along the annular space between the two boundary surfaces.

BRIEF DESCRIPTION OF DRAWINGS:

[0013]

Figure 1 is an elevated, longitudinal cross-section through a static mixer according to the present invention;

Figure 2 is an elevated, transverse cross-section taken through line 2-2 of the mixer depicted in Figure 1;

Figure 3 is a reproduction of the view illustrated in Figure 2, but further including representative fluid stream lines, to illustrate radial cross-flow patterns; and,

Figure 4 is a cut-away perspective view illustrating vortex flow downstream of a single, representative tab.

BEST MODE(S) FOR CARRYING OUT THE INVENTION AND INDUSTRIAL APPLICABILITY:

[0014] Referring now to Figures 1, 2 and 3, there is illustrated an embodiment according to the present invention, in which a static mixer 1, includes a series of tabs 2 that are secured to the side walls 3 of a conduit 4. A central body 5 is arranged in co-axially aligned relation, centrally within the interior of conduit 4, where it occupies a region of inefficient mixing.

[0015] In the illustrated embodiment, that region forms between diametrically-opposed, radially-convergent, cross-stream mixing flows (see Figure 3, in particular) within conduit 4.

[0016] Static mixer 1 comprises conduit 4, in which tabs 2 are each arranged with respective, (leading, upstream) edges 6 adjacent the conduit wall, and respective, (trailing, downstream) opposed edges 7 that are spaced radially inwardly from the conduit wall 3. Tabs 2 operate as fluid foils which, with fluid flowing through the mixer, have greater fluid pressures manifest against their upstream faces 8 (see Figure 1) and reduced fluid pressures against their downstream faces 9 (see Figure 1). This pressure difference in the fluid adjacent, respectively, the mutually opposed faces of each of the tabs then causes the longitudinal flow over and past each tab to be redirected (as is illustrated by the various flow streamlines that are shown in the various figures), thereby resulting in the addition of a radial cross-flow component to the longitudinal flow of fluid through the conduit 4.

[0017] With body 5 occupying the zone of relatively poor mixing as described above, the fluid itself is precluded from forming eddies in that zone, in which the fluid would not be as thoroughly admixed with the bal-

ance of the fluid flow.

[0018] In a particularly preferred embodiment, body 5 comprises a heat transfer body, adapted to exchange heat with the fluid passing through the conduit. This allows a manufacturer to not only secure improved mixing as aforesaid, but to also increase the amount of heat exchange surface available to alter the temperature of the fluid flow. This is particularly advantageous since the benefit of avoiding boundary layer "insulation" effects as discussed in relation to the boundary surface described in US-A-4 929 088 is true for both that boundary surface, and for the heat exchange surface of the central body 5.

[0019] In a further embodiment according to the present invention, the central body 5 is a cross-flow filter element. As will be apparent to persons skilled in the art, in light of the present invention, the boundary layer advantages associated with thermal transfer are applicable in achieving cross-flow filtration advantages too.

[0020] In operation, the improved static mixing according to the present invention is performed over a longitudinal extent of a mixing volume having an annular cross-section, located between the central body 5 and side walls 3 of conduit 4. More specifically, there is cross-stream mixing in the longitudinal fluid flow through the present apparatus, in which tabs 2 redirect a longitudinal fluid flow from the outer, fluid containment boundary surface of side walls 3, across an intervening space having an annular cross-section towards the inner boundary surface defining the outermost extent of central body 5. Preferably, tabs 2 are ramped and arranged in the fluid flow between the respective boundary surfaces of side walls 3 and central body 5, to cause the fluid to flow over the edges of each tab 2 to deflect the generally longitudinal fluid flow radially inwardly from the fluid containment boundary surface of side wall 3, across the intervening space (having the aforesaid annular cross-section), towards an inner boundary surface defined by the outermost surface of central body 5. The inner boundary surface of central body 5, circumscribes a volume which but for the presence of that surface, would permit passage of a central longitudinal flow of substantial, relatively non-uniform mixing.

[0021] As can be seen from all Figures 1 to 4, in the shown embodiment, the sides of the ramped portions of the tabs 2 converge towards the edge 7.

[0022] In a particularly preferred form the fluid flow over the edges of each tab results in the flow being deflected inward and up the inclined surface of the tab to generate a pair of tip vortices in the fluid flow past each tab. The vortices of each such pair have mutually opposed rotations, about an axis of rotation oriented generally along the longitudinal "stream-wise" fluid flow direction, along the annular space between the two boundary surfaces.

Claims

1. A static mixer comprising a longitudinally elongated conduit (4) having tabs (2) that are arranged with respective first edges (6) adjacent the conduit wall (3), and respective opposed second edges (7) that are spaced radially inwardly from the conduit wall (3), said mixer (1) further comprising a central body (5) extending generally coaxially along at least a portion of the longitudinal extent of said conduit (4) and defining between said central body's (5) surface and said conduit wall (3), an annular space, wherein said tabs (2) are operable as fluid foils which, with fluid flowing through said mixer conduit (4), have greater fluid pressures manifest against their upstream faces (8) and reduced fluid pressures against their downstream faces (9), and wherein a resultant pressure difference in the fluid adjacent, respectively, the mutually opposed faces (8, 9) of each of the tabs (2) causes a longitudinal flow of fluid through said conduit (4) over and past each said tab (2), to be redirected, thereby resulting in the addition of a radial cross-flow component to the longitudinal flow of fluid through the conduit (4).
2. The static mixer as claimed in claim 1, characterized in that said central body (5) comprises a heat transfer body, adapted to exchange heat with the fluid passing through the conduit (4).
3. The static mixer as claimed in claim 1 or 2, characterized in that said central body (5) is a cross-flow filter element.
4. The static mixer as claimed in claim 1, 2 or 3, characterized in that said tabs (2) are ramped.
5. The static mixer as claimed in claim 4, characterized in that the sides of the ramped portions of the tabs (2) are converging towards the second edges (7).
6. Use of the static mixer as claimed in any one of claims 1 to 5 for mixing a fluid flowing through said conduit (4), wherein radial cross-stream mixing results from said flow redirecting tabs (2) redirecting a longitudinal fluid flow from the conduit wall (3) across an intervening space of annular cross-section towards the surface of the inner body (5).
7. Use as claimed in claim 6, characterized in that said tabs (2) are ramped and arranged in the fluid flow between the respective boundary surfaces, to cause the fluid to flow over the edges of each said tabs (2) to deflect the generally longitudinal fluid flow inwardly from the fluid containment boundary surface, across the intervening annular space towards said inner boundary surface.

8. Use as claimed in claim 7, characterized in that the fluid flow over the edges of each said tabs (2) results in the flow being deflected inwardly and upwardly along an inclined surface of each said tab (2), to thereby generate a pair of tip vortices in the fluid flow past each tab (2), and wherein said vortices associated with each said pair have mutually opposed rotations about an axis of rotation oriented generally along the longitudinal "stream-wise" fluid flow direction, along the annular space between said two boundary surfaces.

Patentansprüche

1. Statischer Mischer, umfassend einen in Längsrichtung langgestreckten Kanal (4), der Vorsprünge (2) hat, die mit jeweiligen ersten Rändern (6) benachbart der Kanalwand (3) angeordnet sind, und mit jeweiligen entgegengesetzten zweiten Rändern (7), welche radial einwärts von der Kanalwand (3) beabstandet sind, wobei der Mischer (1) weiter einen zentralen Körper (5) umfaßt, welcher sich generell koaxial längs von wenigstens einem Teil der Längserstreckung des Kanals (4) erstreckt und zwischen der Oberfläche des zentralen Körpers (5) und der Kanalwand (3) einen ringförmigen Raum begrenzt, worin die Vorsprünge (2) als Fluidstromlinienkörper betreibbar sind, wobei Fluid, das durch den Mischerkanal (4) strömt, größere Fluiddrücke hat, die sich gegen ihre stromaufwärtigen Flächen (8) manifestieren, und verminderte Fluiddrücke gegen ihre stromabwärtigen Flächen (9), und worin eine resultierende Druckdifferenz in dem Fluid benachbart jeweils den gegenseitig entgegengesetzten Flächen (8, 9) von jedem der Vorsprünge (2) bewirkt, daß einer Längsströmung des Fluids durch den Kanal (4) über jeden Vorsprung (2) und über jeden Vorsprung (2) hinaus eine neue Richtung gegeben wird, so daß dadurch die Hinzufügung einer radialen Kreuz- bzw. Querstromkomponente zu der Längsströmung des Fluids durch den Kanal (4) resultiert.
2. Statischer Mischer nach Anspruch 1, dadurch gekennzeichnet, daß der zentrale Körper (5) einen Wärmeübertragungskörper umfaßt, der dazu geeignet ist, Wärme mit dem Fluid auszutauschen, welches durch den Kanal (4) strömt.
3. Statischer Mischer nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß der zentrale Körper (5) ein Kreuz- bzw. Querstromfilterelement ist.
4. Statischer Mischer nach Anspruch 1, 2 oder 3, dadurch gekennzeichnet, daß die Vorsprünge (2) rampenartig bzw. ansteigend sind.

5. Statischer Mischer nach Anspruch (4), dadurch **gekennzeichnet**, daß die Seiten der rampenartigen bzw. ansteigenden Teile der Vorsprünge (2) nach den zweiten Rändern (7) zu konvergieren.

6. Verwendung des statischen Mischers, der in irgendeinem der Ansprüche 1 bis 5 beansprucht ist, zum Mischen eines Fluids, welches durch den Kanal (4) strömt, worin radiales Kreuz- bzw. Querstrommischen von den der Strömung eine neue Richtung gebenden Vorsprüngen (2) resultiert, welche eine Längsfluidströmung von der Kanalwand (3) quer über einen zwischenliegenden Raum des ringförmigen Querschnitts nach der Oberfläche des inneren Körpers (5) zu umleiten.

7. Verwendung nach Anspruch 6, dadurch **gekennzeichnet**, daß die Vorsprünge (2) rampenartig bzw. ansteigend und in der Fluidströmung zwischen den jeweiligen Grenzoberflächen angeordnet sind, um zu bewirken, daß das Fluid über die Ränder von jedem der Vorsprünge (2) strömt, so daß sie die generelle Längsfluidströmung nach einwärts von der Fluideinschließungsgrenzoberfläche quer über den zwischenliegenden ringförmigen Raum nach der inneren Grenzoberfläche zu ablenken.

8. Verwendung nach Anspruch 7, dadurch **gekennzeichnet**, daß die Fluidströmung über die Ränder von jedem der Vorsprünge (2) dazu führt, daß die Strömung nach einwärts und aufwärts längs einer geneigten Oberfläche von jedem Vorsprung (2) abgelenkt wird, so daß dadurch ein Paar Spitzenwirbel in der Fluidströmung über jeden Vorsprung (2) hinaus erzeugt wird, und worin die Wirbel, die jedem genannten Paar zugeordnet sind, gegenseitig entgegengesetzte Rotationen um eine Rotationsachse haben, die generell längs der längsgerichteten "stromweisen" Fluidströmungsrichtung, entlang dem ringförmigen Raum zwischen den beiden Grenzoberflächen gerichtet ist.

Revendications

1. Mélangeur statique comprenant un conduit (4) qui est allongé longitudinalement, comportant des languettes (2) qui sont disposées avec des premiers bords respectifs (6) adjacents à la paroi (3) du conduit, et des seconds bords opposés respectifs (7) qui sont espacés radialement vers l'intérieur par rapport à la paroi (3) du conduit, ledit mélangeur (1) comprenant en outre un corps central (5) qui s'étend d'une manière générale coaxialement le long d'au moins une partie de l'étendue longitudinale dudit conduit (4) et qui définit espace annulaire entre la surface dudit corps central (5) et ladite paroi

(3) du conduit, et dans lequel lesdites languettes (2) peuvent agir en tant que lames de guidage du fluide qui, lorsqu'un fluide traverse ledit conduit (4) du mélangeur, sont soumises à des pressions supérieures du fluide au niveau de leurs faces amont (8) et des pressions réduites de fluide au niveau de leurs faces aval (9), et dans lequel une différence de pression résultante dans le fluide respectivement au voisinage des faces réciproquement opposées (8,9) de chacune des languettes (8) provoque une réorientation d'un écoulement longitudinal de fluide circulant dans ledit conduit (4) au-dessus et au-delà de chacune desdites languettes (2), ce qui conduit à l'addition d'une composante radiale d'écoulement transversal à l'écoulement longitudinal du fluide circulant dans le conduit (4).

2. Mélangeur statique selon la revendication 1, caractérisé en ce que ledit corps central (5) comprend un corps de transfert de chaleur adapté pour échanger de la chaleur avec le fluide circulant dans le conduit (4).

3. Mélangeur statique selon la revendication 1 ou 2, caractérisé en ce que ledit corps central (5) est un élément de filtre à écoulement transversal.

4. Mélangeur statique selon la revendication 1, 2 ou 3, caractérisé en ce que lesdites languettes (2) ont une forme en rampe.

5. Mélangeur statique selon la revendication 4, caractérisé en ce que les côtés des parties en rampe des languettes (2) convergent vers les seconds bords (7).

6. Utilisation du mélangeur statique selon l'une quelconque des revendications 1 à 5, pour le mélange d'un fluide circulant dans ledit conduit (4), un mélange radial à écoulement transversal étant obtenu à partir desdites languettes (2) de réorientation de l'écoulement, qui réorientent l'écoulement longitudinal du fluide depuis la paroi (3) du conduit à travers un espace intercalaire ayant une section transversale annulaire, en direction de la surface du corps intérieur (5).

7. Utilisation selon la revendication 6, caractérisée en ce que lesdites languettes (2) sont conformées en rampe et sont disposées dans l'écoulement du fluide entre les surfaces limites respectives de manière à amener le fluide à circuler au-dessus des bords de chacune desdites languettes (2) pour faire dévier l'écoulement du fluide, qui en général est longitudinal, vers l'intérieur à partir de la surface limite de retenue du fluide, en travers de l'espace annulaire intercalaire en direction de ladite surface limite intérieure.

8. Utilisation selon la revendication 7, caractérisée en ce que l'écoulement de fluide sur les bords de chacune desdites languettes (2) conduit à une déviation de l'écoulement vers l'intérieur et vers le haut le long d'une surface inclinée de chacune desdites languettes (2), de manière à produire ainsi un couple de tourbillons en pointe dans l'écoulement de fluide circulant devant chaque languette (2), et dans lequel lesdits tourbillons associés à chacun desdits couples ont des rotations réciproquement opposées autour d'un axe de rotation orienté d'une manière générale dans la direction de circulation longitudinale du fluide "en forme de courant", le long de l'espace annulaire entre lesdites deux surfaces limites.

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Fig. 1

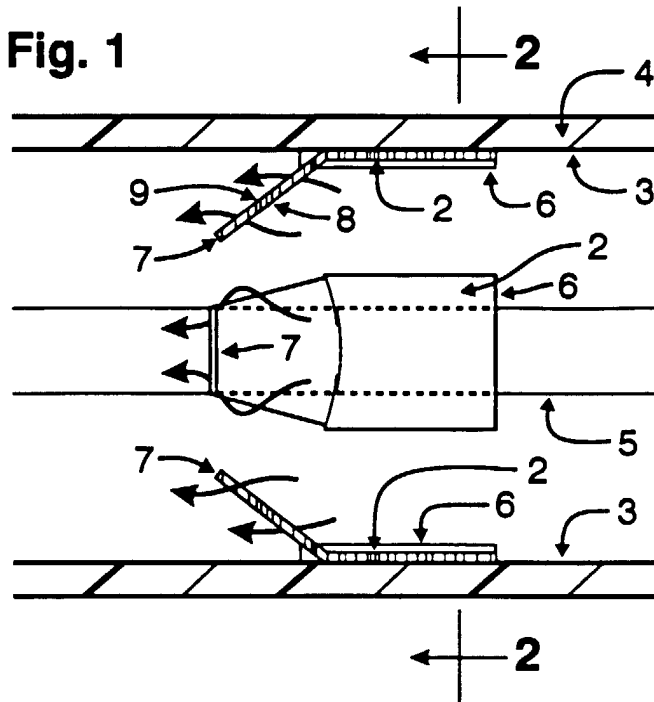


Fig. 2

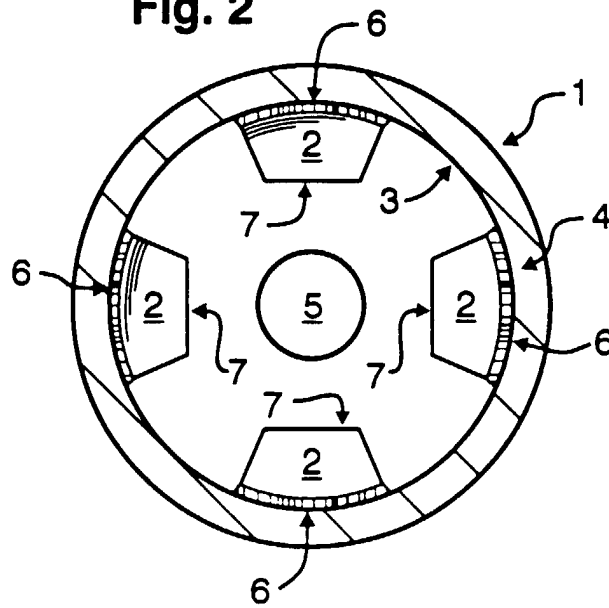


Fig. 3

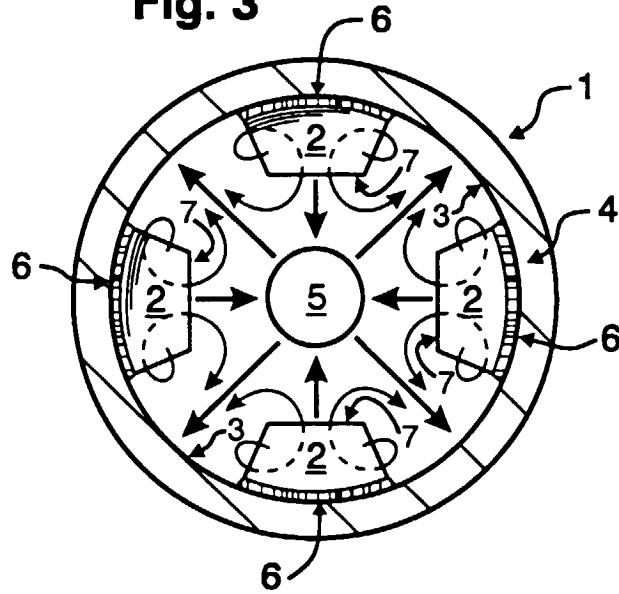


Fig. 4

